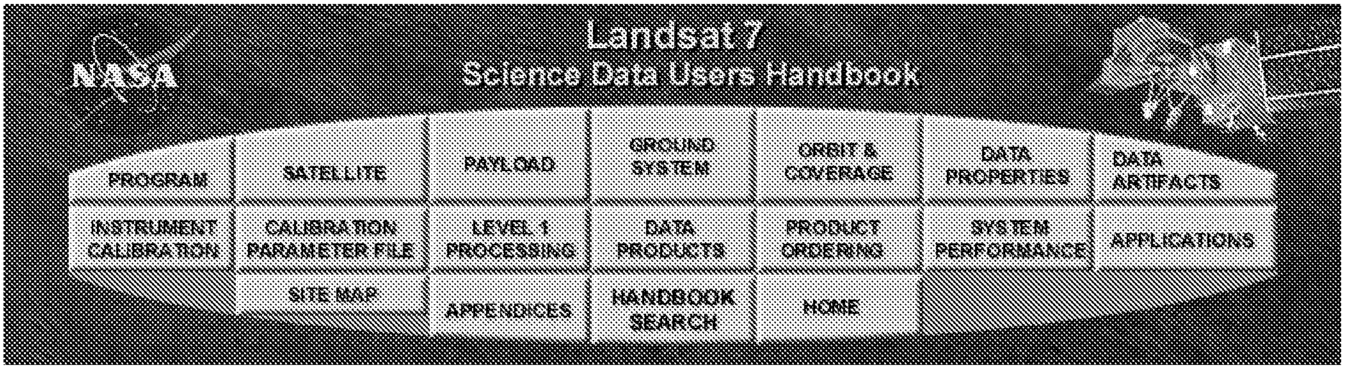
EXHIBIT A



Chapter 11 - Data Products

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11.1 Level 0R Product

Menu

Unlike earlier Landsat programs, the Landsat 7 system was not originally designed to produce high level (i.e. Level 1) products for users. The baselined program philosophy was to provide raw data only which would leave the value added domain for commercial companies. A prevailing "wait and see" position by commercial vendors prompted NASA to add a systematic correction capability to ensure product availability. The primary product for users and vendors seeking higher level processing, however, is 0R data - an essentially raw data form that is marginally useful prior to radiometric and geometric correction. This is readily apparent when viewing a simulated 0R image . A Landsat 7 0R product, however, does contain all the ancillary data required to perform these corrections including a calibration parameter file (CPF) generated by the Landsat 7 IAS.

LPS spatially reformats earth imagery and calibration data into Level 0R data. This involves shifting pixels by integer amounts to account for the alternating forward-reverse scanning pattern of the ETM+ sensor, the odd-even detector arrangement within each band, and the detector offsets inherent to the focal plane array engineering design. All LPs 0R corrections are reversible; the pixel shift parameters used are documented in the IAS CPF.

The LPs 0R output is HDF-EOS formatted and archived. Details of the archival format can be found in the Landsat 7 System Wideband DFCB, Vol. 4.

11.1.1 Product Size

Three options, depicted in Figure 11.2, exist when defining the size or spatial extent of a Landsat level 0R product ordered from the LP-DAAC.

- **Standard Worldwide Reference System (WRS) Scene.** The standard WRS scene as defined for Landsats 4 and 5 was preserved as a product for Landsat 7. The WRS indexes orbits (paths) and scene centers (rows) into a global grid system comprising 233 paths by 248 rows. The path/row notation was originally employed to provide a standard designator for every nominal scene center and allow straight forward referencing without using longitude and latitude coordinates.

  The distance between WRS center points along a path is 161.1 kilometers. A path distance of 90 kilometers before and after a WRS center point defines the standard scene length of 180 km. This length includes 20 scans of overlap with neighboring scenes. The standard WRS scene overlaps neighboring scenes along a path by 5% at the equator and has a width or cross track distance of 185 kilometers.

  Landsat 7 browse is framed according to WRS scenes. An ordered scene will cover the same geographic extent observed in the browse with the following caveat. Standard WRS scenes have 375 scans. Partial scenes (less than 375 scans) may exist at the beginning or end of a subinterval due to the fact that imaging events do not always start and end on scene boundaries. Browse and scene metadata for these occurrences accurately reflect their partial scene nature and geographic extent although partials are currently not offered due to complexities associated with level 1 processing.

- **Subinterval.** An interval is a scheduled ETM+ image period along a WRS path, and may be from one to 90 scenes in length. A subinterval is a contiguous segment of raw wideband data received during a Landsat 7 contact period. Subintervals are caused by breaks in the wideband data stream due to communication dropouts and/or the inability of the spacecraft to transmit a complete observation (interval) within a single Landsat 7 contact period. The largest possible subinterval is 35 scenes long. The smallest possible subinterval is a single ETM+ scene.

- **Partial Subinterval** A partial Landsat 7 subinterval can also be ordered. The partial subinterval is dimensioned according to standard WRS scene width, is at least one WRS scene in length, and can be up to 10 scenes in length if ordered in 0R form or 3 scenes in length in 1G form. A partial subinterval can float or be positioned at any scan line starting point within a subinterval. Partial subintervals are defined by either contiguous WRS locations or a bounding longitude/latitude rectangle. In the latter case, all scan lines touched by the bounding rectangle are included in their entirety.

11.1.2 Product Components

A complete scene-sized 0R product ordered from the LP-DAAC consists of 19 data sets derived from the wideband telemetry, an IAS-generated calibration parameter file, a product specific metadata file, a geolocation index generated by EOSDIS Core System (ECS), and an HDF directory. Therefore, if you order a complete (i.e. all bands) scene-based 0R product it will have 23 distinct files. A brief description of each follows.

- **1 - 9. Earth Image Data** - The unique bands of ETM+ image data comprise nine of the data sets. The data is laid out in a scan line sequential format in descending detector order (i.e. detector 16 followed by detector 15 and so on for the 30 meter bands). Band 6 is captured twice - once in low and the other in high gain mode. Under nominal satellite configuration the low gain form of band 6 will be present in format 1. All image samples or pixels are 8 bits in size.

- **10. Internal calibrator (IC) data - format 1** - IC data for format 1 consists of scan line ordered internal lamp and shutter data for bands 1-5 and blackbody radiance and shutter data for low gain band 6. The data is collected once per scan and structured in a band sequential format in descending detector order (e.g. detector 16 followed by detector 15 and so on for the 30 meter bands).

- **11. Internal calibrator (IC) data - format 2** - IC data for format 2 consists of scan ordered internal lamp and shutter data for bands 7 and 8 and blackbody radiance and shutter data for high gain band 6. The data is collected once per scan and structured in a band sequential format in descending detector order (e.g. detector 16 followed by detector 15 and so on for the 30 meter bands).

- **12. MSCD - format 1.** A logical record of MSCD exists for each data scan present in the 0R product ordered. Each logical record consists of 3 MSCD data values - the first half scan error, the second half scan error, and the scan line direction. This information, which actually applies to the previous scan, is used to compute deviations from nominal scan mirror profiles as measured on the ground and reported in the calibration parameter file. Also included in the MSCD file are scan based values such as time code, gain status and processing errors encountered by LPs The MSCD is trimmed to fit the product ordered although one additional record is added to the file during the subsetting process due to the fact that scan error and direction information corresponds to the prior scan.

- **13. MSCD - format 2.** A duplicate set of MSCD is generated when format 2 is processed and is kept with the product in the event format 1 MSCD is lost or corrupted.

- **14. PCD - format 1** The PCD for format 1 consists of attitude and ephemeris profiles as well high frequency jitter measurements. PCD for the entire subinterval is included with the 0R product regardless of the size of the data set ordered.

- **15. PCD - format 2** A duplicate set of PCD is generated when format 2 is processed and is kept with the product in the event format 1 is lost or corrupted.

- **16. Scan line offsets - format 1.** During LPs processing image data is shifted in an extended buffer to

account for predetermined detector and band shifts, scan line length, and possible bumper wear. The scan line offsets represent the actual starting and ending pixel positions for valid (non-zero fill) earth image data on a data line by data line basis for bands 1 through 6 low gain. The left starting pixel offsets also apply to the IC data.

- **17. Scan line offsets - format 2.** During LPs processing image data is shifted in an extended buffer to account for predetermined detector and band shifts, scan line length, and possible bumper wear. The scan line offsets represent the actual starting and ending pixel positions for valid (non-zero fill) earth image data on a data line by data line basis for bands 6 high gain through 8. The left starting pixel offsets also apply to the IC data.

- **18. Metadata - format 1.** During LPs format 1 processing metadata is generated that characterizes the subinterval's spatial extent, content, and data quality for bands 1 through 6 low gain. This file, in its entirety and original form, accompanies the 0R product.

- **19. Metadata - format 2.** Format 2 metadata is similar but not identical to format 1 metadata. The subinterval-related metadata contents are identical; the scene-related metadata is specific to bands 6 - high gain, 7, and 8. Also, the format 2 metadata does not include cloud cover assessment data or references to browse data products. This file, in its entirety and original form, accompanies the 0R product.

- **20. Metadata - ECS.** A third metadata file generated by ECS during order processing. This file contains product specific information such as corner coordinates and number of scans.

- **21. Geolocation Index.** The geolocation index is also produced by ECS. This table contains scene corner coordinates and their product-specific scan line numbers for bands at all three resolutions. Its purpose is provide for efficient subsetting of a 0R product.

- **22. Calibration parameters.** The IAS regularly updates the CPF to reflect changing radiometric and geometric parameters required for level 1 processing. These are stamped with applicability dates and sent to the LP-DAAC for storage and bundling with outbound 0R products.

- **23. HDF Directory.** A file containing all the pointers, file size information, and data objects required to open and process the 0R product using the HDF library and interface routines.

A user may order a subset of the available bands which will affect the actual file count in a 0R product. In all cases, however, every product includes two PCD files, two MSCD files, three metadata files, the CPF, and the HDF directory. Only the internal calibrator, scan line offset, and earth image file counts are affected by a product possessing less than the full complement of bands.

11.1.3 Product Format

The product delivered to Landsat 7 data users is packaged in HDF - an open standard selected by NASA for Earth Observing System (EOS) data products. HDF is a self-describing format that allows an application to interpret the structure and contents of a file without outside information. HDF allows Landsat 0R products to be shared across different computer platforms without modification and is supported by a public domain software library consisting of access tools and various utilities.

Product users are directed to the Landsat 7 0R Distribution Product Data Format Control Book, Volume 5 (PDF) for details regarding the HDF design used for the 0R product. Included are references to NCSA-authored documentation. New users should begin with **Getting Started with HDF** while the **HDF User's Guide** and **HDF Reference Manual** are excellent resources for the HDF programmer.

11.2 Level 1R Product

Menu

The Level 1R product is a radiometrically corrected 0R product. Radiometric correction is performed using either the CRAM gains in the CPF or gains computed on the fly from the IC data. The choice is available to a user when the product is ordered. The biases used are always calculated from the IC data. Image artifacts such as banding,

striping, and scan correlated shift are removed prior to radiometric correction. Radiometric corrections are not reversible. The 1R product geometry is identical to the input Level OR data.

During 1R product rendering image pixels are converted to units of absolute radiance using 32 bit floating point calculations. Pixel values are then multiplied by 100 and converted to 16 bit integers prior to media output. Two digits of decimal precision are thus preserved. One merely divides each pixel value by 100 to convert the 1R image data back to radiance units. The 16 bit 1R product is twice the data volume of an alike 0R product. **Note for band 6:** A bias was found in the pre-launch calibration by a team of independent investigators post launch. This was corrected for in the LPGS processing system beginning Dec 20, 2000. For data **processed** before this, the 16 bit image radiances are 0.31 w/m2 ster um too high. See the official announcement for more details.

11.2.1 Product Size

Two options exist for users when defining the size or spatial extent of a Landsat level 1R product ordered from the LP-DAAC.

- **Standard Worldwide Reference System (WRS) Scene.** The standard WRS scene, as defined above for the 0R product, can be ordered in 1R form. Partial scenes that may exist at the beginning and end of subintervals may be also be ordered.

- **Partial Subinterval** A partial subinterval can also be ordered in 1R form, although this capability is not scheduled for release until early 2000. Unlike the 0R product the 1R is limited to a maximum of 3 WRS scenes in size. The variably sized 1R product can float or be positioned at any scan line starting point within a subinterval. Alternatively, the product can be defined by up to three contiguous WRS locations.

11.2.2 Product Components

A complete scene-sized 1R product ordered from the LP-DAAC consists of 17 data sets derived from the wideband telemetry, an IAS-generated calibration parameter file, a product specific metadata file, a geolocation index generated by EOSDIS Core System (ECS), and an HDF directory. Therefore, if you order a complete (i.e. all bands) scene-based 0R product it will have 21 distinct files. There are two fewer data files than an alike 0R product due to the fact that the multiple PCD and MSCD files are merged into single consensus files. Please reference the 0R file product for individual file descriptions.

A user may order a subset of the available bands which will affect the actual file count in a 1R product. In all cases, however, every product includes one consensus PCD file, one consensus MSCD files, three metadata files, the CPF, and the HDF directory. Only the internal calibrator, scan line offset, and earth image file counts are affected by a product possessing less than the full complement of bands.

11.2.3 Product Format

The 1R product is delivered to users only in the HDF format. The HDF 0R and 1R formats are nearly identical. Exceptions include the united PCD and MSCD files and an enhanced product specific metadata file that reflects 1R correction characteristics. Please refer to the Landsat 7 0R Distribution Product Data Format Control Book, Volume 5 (PDF) for details regarding HDF specifics. Additional information unique to the 1R product can be found in the ESDIS Level 1 Product Generation system Output Files DFCB (PDF).

11.3 Level 1G Product

Menu

The 1G product available to users from the LP-DAAC is a radiometrically and systematically corrected 0R image. The term systematic refers to the nature of geometric corrections applied. The correction algorithms model the spacecraft and sensor using data generated by onboard computers during imaging events. Primary inputs are the PCD, which includes the attitude and ephemeris profiles, the definitive ephemeris (if available) and the MSCD. Refined parameters from the CPF are also used to improve the overall geometric fidelity of the 1G product.

During processing the 0R image data undergoes two-dimensional resampling according to user-specified parameters including output map projection, rotation angle, pixel size, and resampling kernal. The seven map

projections supported are:

- Universal Transverse Mercator
- Lambert Conformal Conic
- Polyconic
- Transverse Mercator
- Polar Stereographic
- Hotine Oblique Mercator A
- Hotine Oblique Mercator A
- Space Oblique Mercator

Associated with each projection is a unique set of projection parameters that must be specified when ordering a level 1 product. These parameters flow from the USGS General Cartographic Transformation Package and are specified similarly.

The WGS84 ellipsoid is employed as the Earth model for coordinate transformation. The end result is a geometrically rectified product free from distortions related to the sensor (e.g. jitter, view angle effects), satellite (e.g. attitude deviations from nominal), and Earth (e.g. rotation, curvature). A subset of a full scene in Figure 11.4 illustrates the distortion-free characteristics of a 1G product.

The systematic 1G correction process does not employ ground control or relief models to attain absolute geodetic accuracy. Residual error in the systematic 1G product will be approximately 250 meters (1 sigma) in flat areas at sea level. Precision correction employs ground control points to reduce geodetic error of the output product to approximately 30 meters. This accuracy is attained in areas where relief is moderate. Terrain correction processing employs both ground control points and digital elevation models to reduce geodetic error of the output product to less than 30 meters in areas where terrain relief is substantial. Users requiring higher level products would be best served ordering level 0R data for in-house processing or contacting a value added service organization with such capabilities.

11.3.1 Conversion to Radiance

During 1G product rendering image pixels are converted to units of absolute radiance using 32 bit floating point calculations. Pixel values are then scaled to byte values prior to media output. The following equation is used to convert DN's in a 1G product back to radiance units:

$$\mathbf{L_\lambda = "gain" * QCAL + "offset"}$$

which is also expressed as:

$$\mathbf{L_\lambda = ((LMAX_\lambda - LMIN_\lambda)/(QCALMAX\text{-}QCALMIN)) * (QCAL\text{-}QCALMIN) + LMIN_\lambda}$$

where:

L_λ = Spectral Radiance at the sensor□s aperture in watts/(meter squared * ster * µm)

"gain" = Rescaled gain (the data product "gain" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * µm)

"offset" = Rescaled bias (the data product "offset" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * µm)

QCAL = the quantized calibrated pixel value in DN

$LMIN_\lambda$ = the spectral radiance that is scaled to QCALMIN in watts/(meter squared * ster * µm)

$LMAX_\lambda$ = the spectral radiance that is scaled to QCALMAX in watts/(meter squared * ster * µm)

QCALMIN = the minimum quantized calibrated pixel value (corresponding to $LMIN_{\lambda}$) in DN
= 1 (LPGS Products)
= 0 (NLAPS Products)

QCALMAX = the maximum quantized calibrated pixel value (corresponding to $LMAX_{\lambda}$) in DN
= 255

The LMINs and LMAXs are the spectral radiances for each band at digital numbers 0 or 1 and 255 (i.e QCALMIN, QCALMAX), respectively. LPGS used 1 for QCALMIN while NLAPS used 0 for QCALMIN for data products processed before April 5, 20004. NLAPS from that date now uses 1 for the QCALMIN value. Other product differences exist as well. One LMIN/LMAX set exists for each gain state. These values will change slowly over time as the ETM+ detectors lose responsivity. Table 11.2 lists two sets of LMINs and LMAXs. The first set should be used for both LPGS and NLAPS 1G products created **before** July 1, 2000 and the second set for 1G products created **after** July 1, 2000. Please note the distinction between acquisition and processing dates. Use of the appropriate LMINs and LMAXs will ensure accurate conversion to radiance units. **Note for band 6:** A bias was found in the pre-launch calibration by a team of independent investigators post launch. This was corrected for in the LPGS processing system beginning Dec 20, 2000. For data **processed** before this, the image radiances given by the above transform are 0.31 w/m2 ster um too high. See the official announcement for more details.

Table 11.2 ETM+ Spectral Radiance Range watts/(meter squared * ster * µm)

Band Number	**Before July 1, 2000**				**After July 1, 2000**			
	Low Gain		**High Gain**		**Low Gain**		**High Gain**	
	LMIN	LMAX	LMIN	LMAX	LMIN	LMAX	LMIN	LMAX
1	-6.2	297.5	-6.2	194.3	-6.2	293.7	-6.2	191.6
2	-6.0	303.4	-6.0	202.4	-6.4	300.9	-6.4	196.5
3	-4.5	235.5	-4.5	158.6	-5.0	234.4	-5.0	152.9
4	-4.5	235.0	-4.5	157.5	-5.1	241.1	-5.1	157.4
5	-1.0	47.70	-1.0	31.76	-1.0	47.57	-1.0	31.06
6	0.0	17.04	3.2	12.65	0.0	17.04	3.2	12.65
7	-0.35	16.60	-0.35	10.932	-0.35	16.54	-0.35	10.80
8	-5.0	244.00	-5.0	158.40	-4.7	243.1	-4.7	158.3

11.3.2 Radiance to Reflectance

For relatively clear Landsat scenes, a reduction in between-scene variability can be achieved through a normalization for solar irradiance by converting spectral radiance, as calculated above, to planetary reflectance or albedo. This combined surface and atmospheric reflectance of the Earth is computed with the following formula:

$$\rho_p = \frac{\pi \cdot L_{\lambda} \cdot d^2}{ESUN_{\lambda} \cdot \cos\theta_s}$$

Where:

ρ_p = Unitless planetary reflectance

L_λ = Spectral radiance at the sensor's aperture

d = Earth-Sun distance in astronomical units from nautical handbook or interpolated from values listed in Table 11.4

$ESUN_\lambda$ = Mean solar exoatmospheric irradiances from Table 11.3

θ_s = Solar zenith angle in degrees

Table 11.3 ETM+ Solar Spectral Irradiances

Band	watts/(meter squared * µm)
1	1969.000
2	1840.000
3	1551.000
4	1044.000
5	225.700
7	82.07
8	1368.000

Table 11.4 Earth-Sun Distance in Astronomical Units

Julian Day	Distance	Julian Day	Distance	Julian Day	Distance	Julian Day	Distance	Julian Day	Distance
1	.9832	74	.9945	152	1.0140	227	1.0128	305	.9925
15	.9836	91	.9993	166	1.0158	242	1.0092	319	.9892
32	.9853	106	1.0033	182	1.0167	258	1.0057	335	.9860
46	.9878	121	1.0076	196	1.0165	274	1.0011	349	.9843
60	.9909	135	1.0109	213	1.0149	288	.9972	365	.9833

11.3.3 Band 6 Conversion to Temperature

ETM+ Band 6 imagery can also be converted from spectral radiance (as described above) to a more physically useful variable. This is the effective at-satellite temperatures of the viewed Earth-atmosphere system under an assumption of unity emmissivity and using pre-launch calibration constants listed in Table 11.5. The conversion formula is:

$$T = \frac{K2}{\ln\left(\frac{K1}{L_\lambda} + 1\right)}$$

Where:

T = Effective at-satellite temperature in Kelvin

K2	=	Calibration constant 2 from Table 11.5
K1	=	Calibration constant 1 from Table 11.5
L	=	Spectral radiance in watts/(meter squared * ster * □m)

Table 11.5 ETM+ Thermal Band Calibration Constants		
	Constant 1- **K1** watts/(meter squared * ster * µm)	Constant 2 - **K2** Kelvin
Landsat 7	666.09	1282.71

11.3.4 Product Size

The same two 1R options exist for users when defining the size or spatial extent of a Landsat level 1G product ordered from the LP-DAAC.

- **Standard Worldwide Reference System (WRS) Scene.** The standard WRS scene, as defined above for the 0R product, can be ordered in 1G form. Partial scenes that may exist at the beginning and end of subintervals may be also be ordered.

- **Partial Subinterval.** A partial subinterval can also be ordered in 1G form. Unlike the 0R product the 1G is limited to a maximum of 3 WRS scenes in size. The variably sized 1G product can float or be positioned at any scan line starting point within a subinterval. Alternatively, the product can be defined by up to three contiguous WRS locations.

11.3.5 Product Components

The 1G product ordered from the LP-DAAC consists of the corrected image files and descriptive metadata. All other ancillary files delivered with the 0R and 1R products are not included. A user may order a subset of the available bands which affects the actual file count in a 1G product.

11.3.6 Product Format

The 1G product can be packaged into one of following user-specified output formats:

- **HDF.** The HDF packaging format used for the 0R and 1R products is also used for structuring the 1G. The design employs external elements for the band files and metadata. These are standalone files that are referenced via tags and pointers residing in an HDF directory. External elements provide users with two processing options - exploit the NCSA HDF libraries for data access or process the data files directly using homegrown code.

  The number of files comprising an HDF-formatted 1G product will vary according to the number of bands ordered. A product with a full band complement has 11 files - the HDF directory, a metadata file, and a separate file for each band. The HDF directory and metadata files are always present regardless of bands ordered. Please refer to the Landsat 7 0R Distribution Product Data Format Control Book, Volume 5 (PDF) for details regarding band file specifics. The 1R metadata file description can be found in the ESDIS Level 1 Product Generation System Output Files DFCB (PDF).

  The HDF format can be specified for any type of 1G product ordered from the LP-DAAC.

- **Fast.** The Fast Format was originally developed by EOSAT as a means for quickly accessing Landsat 4 and 5 image data. Its structure is straightforwardly simple. Each band is self contained in its own file (i.e external element style). A header file containing three records accompanies the image data. The three records in order

of appearance are labeled administrative, radiometric, and geometric respectively. Sensor specific information is placed in the administrative record, gains and biases can be found in the radiometric record while projection information and image coordinates are stored in the geometric record. A single header file along with the image files constitute the Fast product.

A derivative of the Fast Format (Fast-L7) used by EOSAT for Landsat (FAST-B) and Indian Remote Sensing products (Fast-C) was created for Landsat 7. Several differences are worth noting. File names are now included in the administrative record which allows for direct file access. A separate header file now accompanies the panchromatic, thermal and VNIR/SWIR band groups for Landsat 7. For Fast-B and Fast-C all bands were resampled to a common grid cell size thus permitting a single header file. In all likelihood each of the band groups for Landsat 7 will be resampled to a common resolution (i.e. 15, 30, & 60 meters) thus requiring a distinct header file for each.

All critical fields required for product ingest were left unchanged in the Fast L-7A Format. As a consequence Heritage Fast readers residing on user systems can be used for the Landsat 7 Fast formatted product. A full layout of the Fast L-7A Format can be found in the the ESDIS Level 1 Product Generation system Output Files DFCB.

The Fast-L7 format supports all variations of the 1G product.

- **GeoTIFF.** Geographic tagged image file format (GeoTIFF) is based on Adobe's TIFF - a self-describing format developed to exchange raster images such as clipart, logotypes, and scanned images between applications and computer platforms. Today, the TIFF image file format is used to store and transfer digital satellite imagery, scanned aerial photos, elevation models, and output from digital cameras. TIFF is the only full-featured format in the public domain, capable of supporting compression, tiling, and extension to include geographic metadata.

  The TIFF file consists of a number of label (tags) which describe certain properties of the file (such as gray levels, color table, byte format, compression size). After the initial tags comes the image data which may be interrupted by more descriptive tags. GeoTIFF refers to TIFF files which have geographic (or cartographic) data embedded as tags within the TIFF file. The geographic data can then be used to position the image in the correct location and geometry on the screen of a geographic information display.

  Baseline TIFF image types can be bilevel, greyscale, palette color, and full color (24 bit). For simplicity's sake the grayscale model was implemented for the Landsat 7 GeoTIFF product. Under this implementation each ordered band is delivered as its own 8 bit greyscale GeoTIFF image. A standard WRS scene possessing the full band complement would thus be comprised of nine separate GeoTIFF images or files. No other files accompany the product. For detailed information regarding the Landsat 7 GeoTIFF implementation please refer to the ESDIS Level 1 Product Generation system Output Files DFCB (PDF). For GeoTIFF details, please download the GeoTIFF Format Specification (PDF) or visit this web site.

  At the present time GeoTIFF format cannot be used for the Space Oblique Mercator and Oblique Mercator projections. Products projected into these reference systems must be formatted using HDF or Fast-L7.

11.4 SLC-Off Product

Menu

An instrument malfunction occurred onboard Landsat 7 on May 31, 2003. The problem was caused by failure of the Scan Line Corrector (SLC), which compensates for the forward motion of the satellite. Subsequent efforts to recover the SLC have not been successful, and the problem appears to be permanent.

The Landsat 7 Enhanced Thematic Mapper Plus (ETM+) is still capable of acquiring useful image data with the SLC turned off, particularly within the central portion of any given scene. Landsat 7 ETM+ will therefore continue to acquire image data in the "SLC-off" mode.

EDC has recently released several Landsat 7 ETM+ SLC-off data products. The first, a gap-present product became available on October 22, 2003. This product release includes all image data acquired by Landsat 7 in SLC-off mode from July 14, 2003 to present, excluding a 2-week interval from 9/3/03 to 9/17/03.

The center of a gap-present SLC-off data product is very similar in quality to previous Landsat 7 data. However, the scene's edges will contain alternating scan lines of missing data (Level 1G) or duplicated data (Level 0Rp or L1R). The precise location of the affected scan lines will vary from scene to scene, and these gaps will not be visible on the browse image preview when ordering SLC-off data. A preliminary report regarding the utility of Landsat 7 SLC-off data is available in PDF form. This report includes input from scientists affiliated with the USGS, NASA, and the Landsat 7 Science Team

The gap-present SLC-off data products now available include Level 0Rp, Level 1R, and Level 1G data, and are distributed as standard Landsat 7 single scene (WRS-2) and multi-scene products. SLC-off Level 1R and Level 1G products were first processed by the Level 1 Product Generation System (LPGS) only. The release date for data products (e.g. Level 1G, Level 1P, and Level 1T) processed through the National Land Archive Production System (NLAPS) was April 5, 2004. A 1G product ordering option can be specified to fill the gaps via interpolation (Figure 11.5)

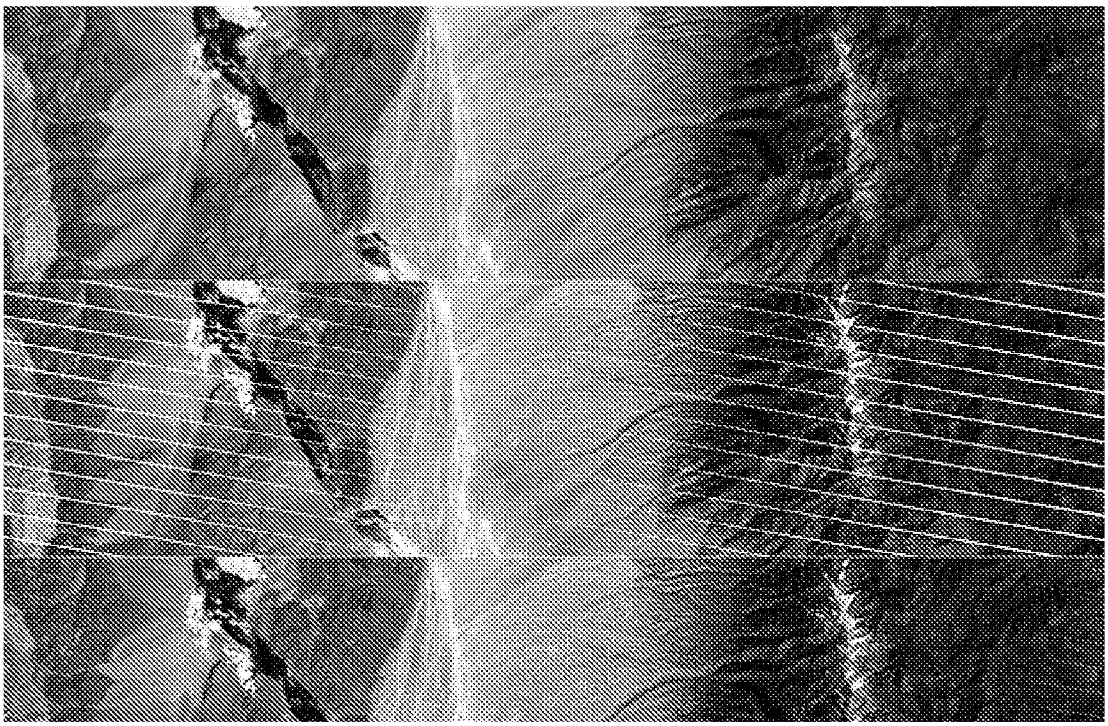

Figure 11.5 Top image: pre-SLC anomaly, middle of image. Middle image: scene after SLC anomaly. Bottom image: scene after SLC anomaly with interpolation.

The second product now being offered (as of May 10, 2004) is in 1G form and has the gap areas filled with Landsat 7 data acquired at a similar time of year and prior to the SLC failure. The two scenes are geometrically registered, and a histogram matching technique is applied to the fill pixels which provides the best-expected radiance values for the missing data.

Both types of SLC-off data products can be searched and ordered via the Earth Explorer, and Global Visualization L7 Image Browser.

EDC has reduced the price of Landsat 7 ETM+ SLC-off scenes with gaps in data resulting from the May 2003 satellite anomaly. Scenes that contain gaps in data have been reduced from $600 to $250. Scenes with the gaps filled in using data acquired prior to the anomaly are offered at a reduced price of $275 as of May 10, 2004.

The USGS, in conjunction with NASA, is continuing to research other methods of providing merged data products and will continue to provide information resulting from this work as it becomes available. More detailed information and data samples of the new gap-filled Landsat 7 products can be found at Landsat 7 gap-filled product description.

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